DOCUMENT RESUME

ED 255 625 SE 045 559

TITLE Science: A Maryland Curricular Framework.
INSTITUTION Maryland State Dept. of Education, Baltimore.
PUB DATE [84]
NOTE 45p.
PUB TYPE Guides - Non-Classroom Use (055)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Biological Sciences; *Curriculum Development; *Educational Objectives; Educational Philosophy; *Elementary School Science; Elementary Secondary Education; Physical Sciences; *Program Development; Science Curriculum; Science Education; *Science Programs; *Secondary School Science
IDENTIFIERS *Maryland

ABSTRACT

This document is designed to assist administrators and teachers in planning, developing, and implementing science programs in kindergarten through grade 12. It provides a philosophical foundation and curricular framework from which educators may construct comprehensive science education programs. The materials presented will aid local school systems in: planning local curricula; developing a local philosophy; defining a local set of goals and subgoals; developing a local scope and sequence; evaluating the extent that the goals and subgoals are contained in current curricular offerings; and identifying needed curricular content and instructional strategies. The document is organized in five major sections: (1) a consideration of philosophy, in which the nature of science is defined and its relationship with society, the learner, and the school curriculum is defined; (2) a list of five goals and their respective subgoals; (3) a list of behavioral statements which provide further definition for each subgoal; (4) illustrative objectives, showing how goals and subgoals may be treated at particular grade levels; and (5) a discussion of how to develop and use goals, subgoals, and objectives in the preparation of science scopes, sequences, and instructional units. (JN)

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SCIENCE

A MARYLAND CURRICULAR FRAMEWORK

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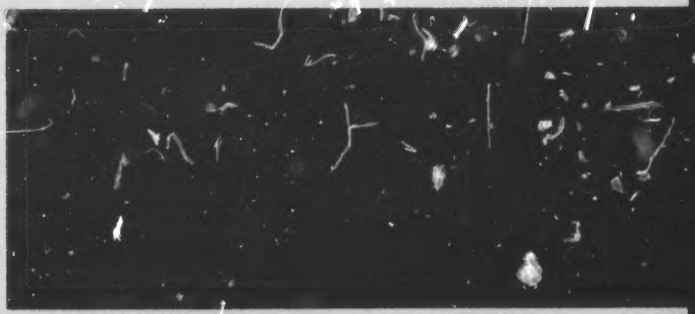

ACKNOWLEDGEMENTS

This framework—its goals, subgoals, expectancies, and illustrative objectives—was developed under the direction of the Maryland Science Task Force, chaired by Susan P. Snyder, Specialist in Science, Maryland State Department of Education.

Sincere appreciation is extended to the following who also contributed to the production of this guide:

The Maryland Science Review Panel
The Maryland science supervisors
Science education specialists from Maryland's institutions of higher education
Local science teachers

Maryland State Board of Education

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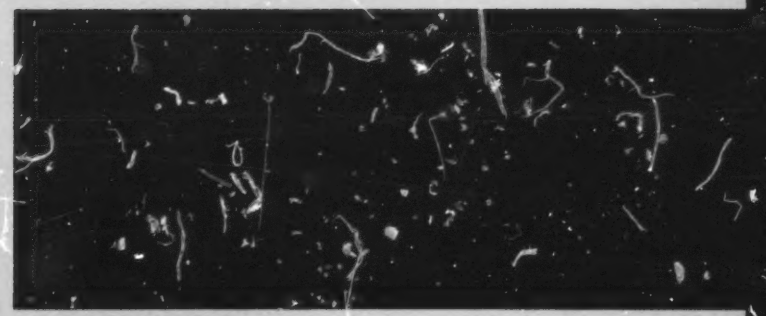


FOREWORD

The accelerated growth of scientific knowledge during the past several decades is unparalleled in history. Information processing, communications, transportation, agriculture, and medicine are just a few examples of fields which, as a result of scientific research, have undergone rapid change profoundly affecting our society. Indeed, our economy today is increasingly dependent upon scientific and technological advances.

In view of these developments, it is more critical than ever that schools provide quality instruction in the physical and biological sciences. Such programs must produce the increasing number of highly trained people needed for today's technology-oriented job market. In addition, the schools should prepare all students to understand and manage the products of our new technological age. This means that our science programs must not only provide students with the fundamental concepts of science but also teach them to reason logically and to critically evaluate the results and conclusions of scientific investigations.

The curricular framework set forth in this document provides direction for such a comprehensive approach to science education in Maryland. It is our goal to produce citizens who are capable of making informed decisions about today's complex technological and environmental issues.

David W. Hornbeck
State Superintendent of Schools

PREFACE

During the last few decades, our economy and society have become science and technology dependent. Never before has it been so important for students to have a basic understanding of the nature of the scientific enterprise.

In response to this, the Maryland State Board of Education, through the State Superintendent of Schools, formed a science task force charged with developing goals for a comprehensive K-12 science program. The task force was made up of ten local science supervisors and was coordinated by the state specialist in science and a university intern.

The group reviewed curricular materials related to science education from many sources and numerous states. Background material from respected science educators was also considered as the task force developed their philosophy and the five goals of the science program.

Next, five subcommittees were formed, each chaired by one or more task force members and made up of local teachers, specialists, administrators, and university consultants. The subcommittees developed the refined subgoals for each goal as well as expectancies which would delineate the possible scope of the subgoals.

Reviews of the final document were made by nationally recognized experts in science education, teachers, supervisors, and scientists from Maryland. A formal review panel, chaired by the state assistant superintendent in instruction, was convened to consider the completed work.

Finally, the State Department of Education funded projects for five local systems to first examine their current programs and then outline and compare their desired science curriculum to the new goals for science. The result of this activity was the production of science curricular models which show alternative methods of reaching the desired outcomes of a K-12 program.

This document summarizes the work directed by the task force and includes a section to assist local school systems in their curriculum development efforts.

INTRODUCTION

A Statement of Purpose

Science: A Maryland Curricular Framework is designed to assist administrators and teachers in planning, developing, and implementing K-12 science programs. It provides a philosophical foundation and curricular framework from which educators may construct comprehensive science education programs. The materials presented will aid local school systems in:

Planning local curricula,

Developing a local philosophy,

Defining a local set of goals and subgoals,

Developing a local scope and sequence,

Evaluating the extent that the goals and subgoals are contained in current curricular offerings, and

Identifying needed curricular content and instructional strategies.

This document is organized in five major sections:

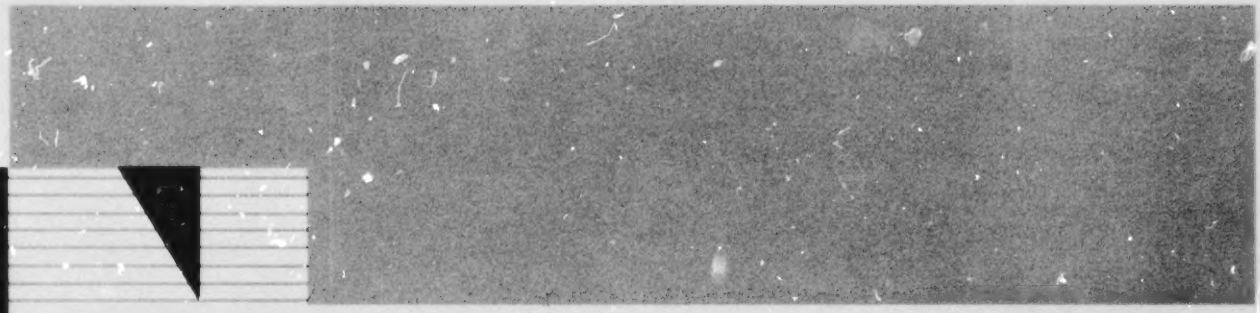
The Philosophy—This defines the nature of science and describes its relationship with society, the learner, and the school curriculum.

Goals and Subgoals—These broad statements of desired outcomes derive from the philosophy and bring direction and clarity to the program.

Expectancies—These behavioral statements provide further definition for each subgoal.

Illustrative Objectives—These sample objectives show how goals and subgoals may be treated at particular grade levels.

Curriculum Development Process—This section describes how to develop and use goals, subgoals, and objectives in the preparation of science scopes, sequences, and instructional units.



PHILOSOPHY

ature of Science

Throughout history, human beings have been preoccupied with trying to understand the world around them. Since the days of the Greek philosophers the search for explanations of observed phenomena in the universe has been categorized as science. Today, scientific explanations must be based on relationships developed from empirical data and the theories developed to unify those relationships.

Our current scientific enterprise can be thought of as having two major components: scientific knowledge and scientific inquiry. Scientific knowledge represents, at a given time, the laws, principles, theories, concepts, and data bases which the scientific community recognizes as being the most accurate and useful.

Scientific inquiry is made up of the procedures used to generate scientific knowledge and is grounded in sound cognitive, manipulative, and investigative processes. Observations are made with care, with attention to detail and as free from inference and bias as possible. Questions which arise from these observations are chosen and point the way to experimentation. From these questions hypotheses are generated and studies are designed to test the hypotheses. Variables must be identified, experiments designed, data gathered, results analyzed, conclusions drawn, and predictions made.

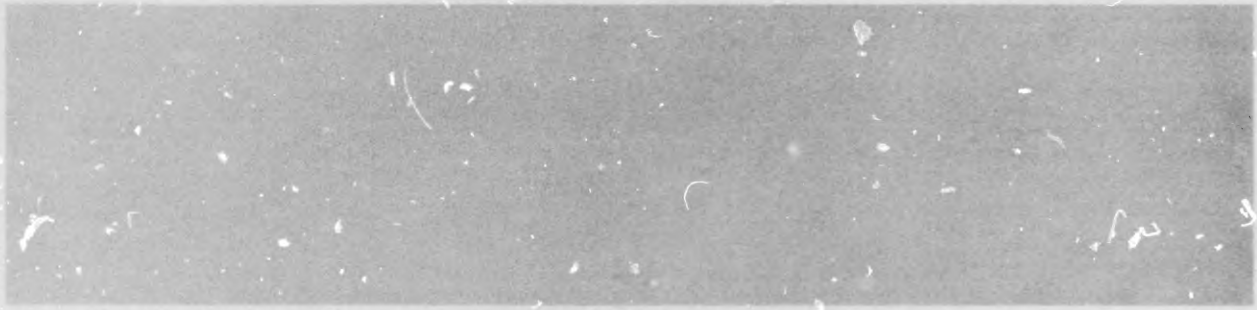
Science is, therefore, a creative process which attempts to discover and understand. At times the discoveries are new, at other times they are merely alterations of current concepts. Regardless, science questions all things, rejects the labeling of statements as unalterable, and opens itself to continual scrutiny and modification.

As our scientific knowledge grows, we should always be prepared to alter the point of view we use to order our experiences and guide our investigations. In this way, science is a never ending process of discovery, interpretation, and evaluation.

Science and Society

Over the last several decades, the rate of scientific knowledge acquisition has increased dramatically. Fields such as medicine, space science, particle physics, and organic chemistry continue to produce information faster than any one individual, or indeed group of individuals, can process. The demand for science to investigate and solve many of the world's problems has served to accelerate further this growth of knowledge. Technology—the eager, energetic and, at times, precocious child of science—has also contributed to the flood of information. Working hand-in-hand, science and technology have used this inundation of knowledge to raise the quality of life to heights unparalleled in human history.

As is so often the case with growth and advancement, this new knowledge has a price, and that price is exacted upon every citizen in today's society. When scientific research suggests new and daring possibilities in the areas of genetic engineering, bionics, and artificial life-support, people find themselves dealing with moral and ethical questions that have never been a part of society's concerns. When technology fills the marketplace with inventions, gadgets, and sophisticated hardware, consumers face bewildering decisions about what to purchase and how to intelligently use these innovations. When scientific investigation forsees difficulties in the availability of future energy sources, pollution, or environmental degradation, the impact of these findings ripples through the very fabric of society, affecting economics, politics, jobs, life-styles, and the quality of living for all citizens. In addition, when there is a rapid growth of technology-dependent industry, there are increased demands for a technologically literate labor force.



To meet these challenges, it is necessary for the science curriculum of our schools to address the attitudes, processes, tools, knowledge, and societal implications of science. This comprehensive approach to science education requires that learners receive the essential readiness skills to become scientifically literate. Such skills go beyond learning; they give individuals a foundation for making sound decisions, for understanding recent scientific advances and their implications, for being prepared for a new job market, and for developing a feeling of control over their lives.

Science and the Learner

The simple, fundamental need of human beings to know about the universe and themselves gave birth to science with all its formulae, methods, and laws. Such a longing to know is evident even in the youngest child, to whom the world is unknown and is fair game for any and all explorations. When youngsters utter their first questions of "why" or "how" or "what," they begin, for themselves, their own brand of scientific inquiry. As they uncover answers to the questions they ask, their questioning behavior is reinforced, and they eagerly pursue further inquiry.

Educators have the responsibility, and indeed the challenge, of developing or selecting curricula that tap that open-mindedness and curiosity. In early grades, the science curriculum must provide the concrete experiences that can be readily understood by young learners. These experiences will help to satisfy the immediate learning needs of the students and can function as enablers for the science work to come in higher grades.

The students' need to know includes a need to learn how to investigate problems using dependable methods. This is a cognitive maturing process, where superstitious or magical beliefs and hit-or-miss techniques of discovery are replaced with concepts based upon evidence and new discovery techniques that include valid methodologies.

It is especially important to consider the self-oriented nature of young science students. Their world is slow to release its mysteries unless there are direct, hands-on experiences with which they can interact and to which they can personally relate. Students' truths are those which they discover, not those which are dictated. The imperative to science instruction is clear: approach science as a student activity—an activity that contains a wealth of opportunities for personal inquiry, that encourages and enlivens the natural and immense capacity of children to question and learn, and that deeply respects the force of curiosity which sponsors that capacity.

The exuberance for inquiry and discovery in older science students is often less overt than in their younger counterparts. These students, struggling with their own changes and maturation, are more self-aware and restrained, more sensitive to problems of criticism and self-esteem, and find themselves grappling with a world that offers endless distractions. Frequently, their expressions of curiosity are tempered by fears of failure or embarrassment, and they may choose to suppress their needs to actively investigate and explore. At the same time, they are becoming more mature intellectually and are better able to deal with abstract and formal ideas and concepts. Here, science instruction must focus upon providing these students with a learning environment that is challenging and stimulating, yet not intimidating. Curriculum planners must recognize the innate but dormant excitement for learning these students possess, and provide materials that stimulate their higher level thinking, that sharpen their critical senses and that rekindle their aptitude for wonder.

Regardless of age, inquiry begins most effectively and spontaneously when science students encounter phenomena or concepts that are difficult for them to explain or that are somewhat beyond their experience and knowledge bases. Here, students must attempt to fit their observations into their existing mental structures. As a result, their mental structures change to accommodate and assimilate these new ideas. When students are allowed to learn in this way, several very positive things take place; students identify learning as a personal experience; they improve their own sense of identity and self-esteem; and their rewards for learning, as was the case in their extreme youth, become intrinsically satisfying and therefore self-perpetuating.

The Science Curriculum

Science is that component of the school curriculum where student inquiry and discovery can develop and flourish. Science instruction encourages questioning, examining, probing, and exploring; it allows students to cultivate personal strategies for learning and problem-solving. Such investigative strategies incorporate skills that students can apply to all facets of the school curriculum and enable them to direct their own learning experiences inside and outside of the school setting.

The science curriculum must be consistent with scientific procedures and goals, take into account the interests and abilities of children, and respond to the technological and human needs of our society. Characteristics of such a curriculum include:

- a comprehensive kindergarten through twelfth grade program involving the disciplines of science;
- an activity approach to science, with abundant concrete, hands-on laboratory experiences where students learn the content and processes of science;
- inquiry experiences which stress the development of critical thinking skills and are not limited to replicating existing studies;
- the presentation of concepts which are compatible with the developmental levels of the students;
- an emphasis on creative problem solving;
- a sensitivity to the wide range of student capabilities and to programs and materials that will give all students opportunities to succeed in science experiences;
- attention to the social and historical context of scientific discoveries.

Science is dependent upon the exact meanings of the words it uses and the precision of the mathematics it employs and thus embraces many other aspects and disciplines of the school curriculum as allies to its purpose. Science students must bring together their knowledge of language arts, mathematics, social studies, logic, and critical thinking in such a way as to expand their own learning and literacy and to systematically answer the questions they themselves generate. Conversely, science can also provide other curriculum areas with purposeful activities to enhance their objectives. The science curriculum is a multidisciplinary meeting ground where procedures and methods of obtaining knowledge are as much a part of the educational process as the knowledge itself.

SCIENCE GOALS AND SUBGOALS

These five goals and their respective subgoals and expectancies represent a broad guideline for K-12 science programs in the school systems of Maryland. The goals and subgoals amplify different aspects of a program for developing scientific literacy.

These goals are not discrete but are designed to be used together for the design of comprehensive programs. Any individual lesson or unit may be leading toward the achievement of many of the goals.

Local science programs in Maryland must encompass all of the goals and respective subgoals at the elementary and again at the secondary level.

GOAL 1

To develop positive attitudes toward science and its relevance to the individual, society, and the environment.

Those who participate in science typically exhibit attitudes that reflect upon the nature of their discipline. While they may be driven by curiosity or a sense of awe at the orderliness of the natural world, they understand their responsibility to maintain objectivity during their research and analysis and to consider the consequences of their investigations.

Goal 1 describes those aspects of scientific attitudes and perspectives which are essential to a comprehensive science curriculum. It also includes a study of the relationship of science to society and the environment as well as an understanding of the history of science.

Subgoals

1.1 To value science as a worthy endeavor.

1.2 To recognize science as a human endeavor.

1.3 To exhibit awareness of the orderliness and aesthetics in the environment.

1.4 To recognize interactions among science, technology, and society.

GOAL 2

To develop and apply, through science experiences, rational and creative thinking processes for problem solving.

The skills used in scientific investigations are those which form the underpinnings of science methodology. Careful observations are made which lead to the generation of testable questions. From these questions, hypotheses are generated and tested through experimentation.

Goal 2 includes those basic and complex cognitive skills which are essential for scientific inquiry. These range from such basic processes as observing, classifying, and inferring to such complex processes as developing hypotheses, designing experiments, and drawing conclusions.

Subgoals

2.1 To use observation to investigate the environment.

2.3 To use questions for defining problems.

2.4 To use hypotheses as predictive tools.

2.5 To conduct scientific investigations.

2.6 To organize data for the identification of trends and patterns.

2.7 To use experimental evidence for evaluating hypotheses.

2.8 To apply the results of inquiry and critical thought.

GOAL 3

To employ the language, instruments, and materials of science for collecting, organizing, and communicating information.

The tools of the scientist are many and varied. When instruments can faithfully explore where the senses cannot, these tools are used as extensions and enhancements of human abilities. Whether in the classroom, the laboratory, or the field, scientists must be expert practitioners as they select, design, and manipulate apparatus of measurement and research.

In addition, words and terms must be operationally defined and used appropriately. Data must be accurately quantified and properly analyzed. Library research should encompass a variety of sources and the findings of scientific investigations should be clearly written and well supported. Goal 3 includes these manipulative and communicative skills.

Subgoals

3.1 To apply the appropriate skills and mathematical techniques necessary for collecting, organizing and interpreting data.

3.2 To communicate in a manner that is consistent with scientific procedures.

3.3 To use laboratory apparatus in a skillful manner.

3.4 To demonstrate proper techniques for handling, manipulating, and caring for science materials.

GOAL 4

To acquire and apply scientific knowledge—its concepts, theories, principles, and laws—to interpret the natural world.

Scientific knowledge, a product of inquiry, is that body of information representing those explanations of the universe which are presently accepted. Using traditional divisions to describe the nature of this knowledge, Goal 4 includes the major content areas of the physical sciences (including chemistry and physics), the life sciences and the earth sciences. These divisions are utilized only for organizational purposes. No one area of science could exist by itself; each is strongly dependent on the others for information, concepts, and theories.

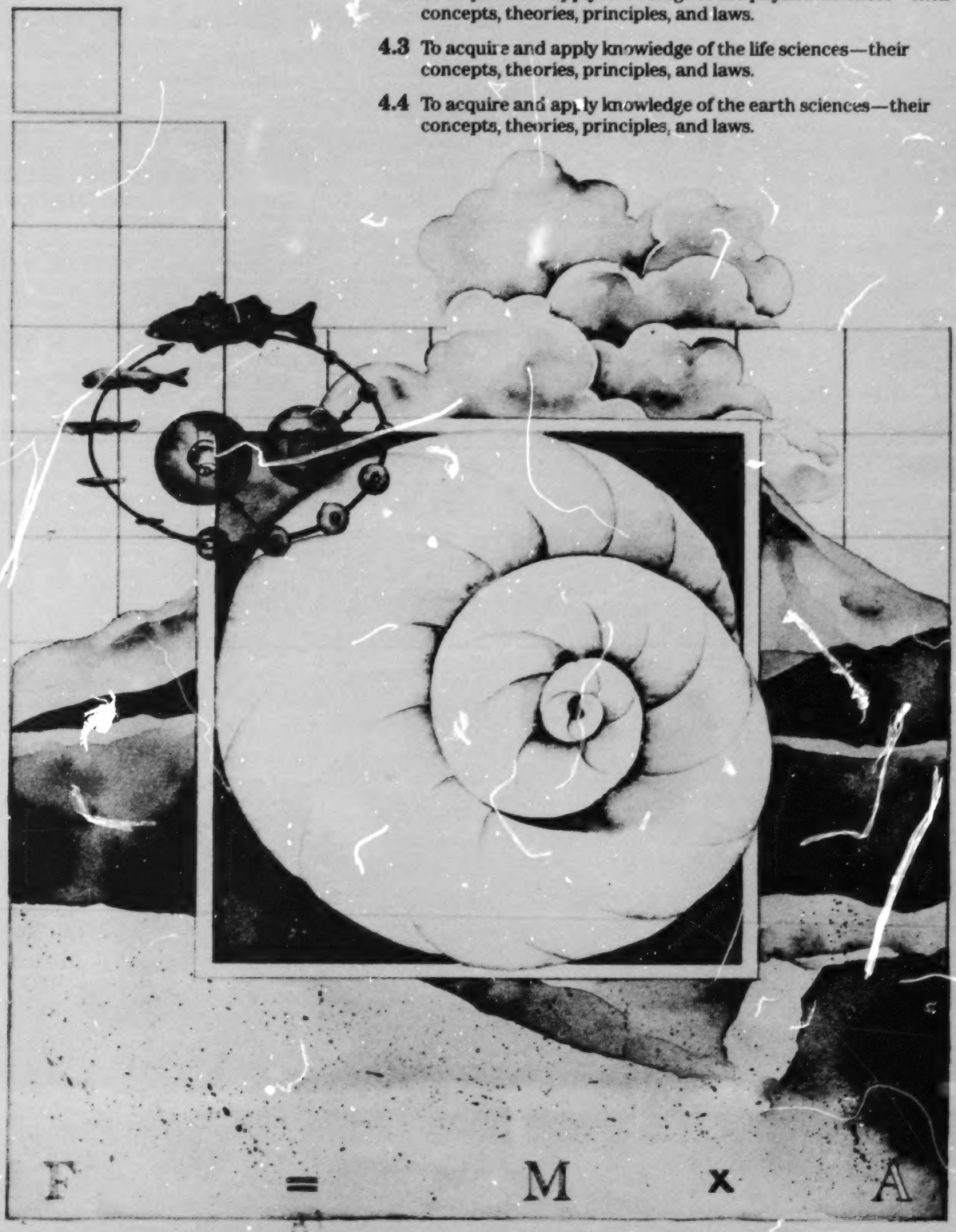
Subgoals

4.1 To describe the nature of science.

4.2 To acquire and apply knowledge of the physical sciences—their concepts, theories, principles, and laws.

4.3 To acquire and apply knowledge of the life sciences—their concepts, theories, principles, and laws.

4.4 To acquire and apply knowledge of the earth sciences—their concepts, theories, principles, and laws.

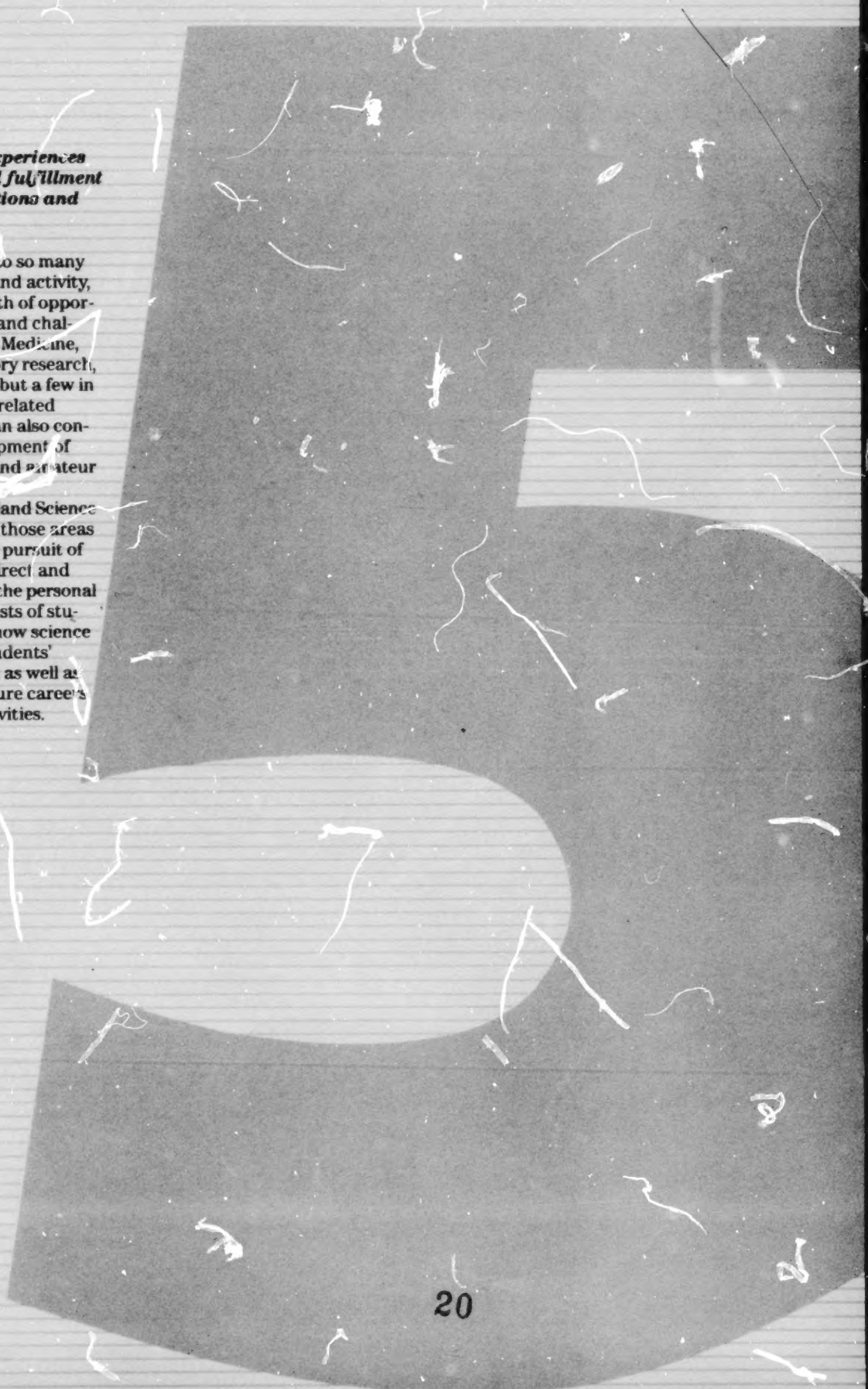


GOAL 5

To utilize science experiences in the planning and fulfillment of personal aspirations and career decisions.

Because it speaks to so many areas of human life and activity, science offers a wealth of opportunities for fulfilling and challenging occupations. Medicine, engineering, laboratory research, and field studies are but a few in a long list of science-related vocations. Science can also contribute to the development of interesting hobbies and amateur activities.

Goal 5 of the Maryland Science Framework outlines those areas where the study and pursuit of science can have a direct and lasting impact upon the personal objectives and interests of students. It focuses on how science can contribute to students' feelings of self-worth as well as their selection of future careers and leisure time activities.



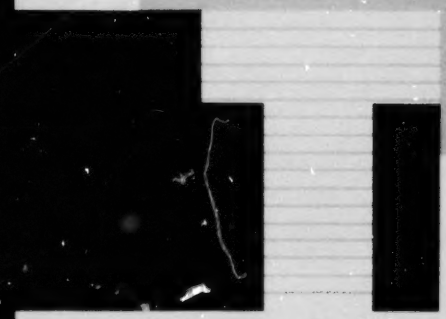
Subgoals

5.1 To relate science concepts and skills to vocations and avocations.

5.2 To view persons in a variety of science-related vocations and avocations as role models.

5.3 To demonstrate vocational planning skills.

5.4 To participate in creative science experiences that may enhance one's self-concept.



EXPECTANCIES

These learner behaviors further define what the scope of each subgoal could be. They indicate a range of outcomes that could be expected for different students by the time they have completed their science program.

Goal 1 To develop positive attitudes toward science and its relevance to the individual, society, and the environment.

Subgoal 1.1 To value science as a worthy endeavor.

The learner:

1.1.1 Displays curiosity about natural phenomena.
1.1.2 Questions myths and superstitions as well as accepted scientific findings.
1.1.3 Expresses the need for acquiring, organizing, and evaluating data.
1.1.4 Reports data objectively and submits findings to the scrutiny of others.
1.1.5 Justifies the necessity for logical thought when progressing from raw data to conclusions.
1.1.6 States the role of assumptions in scientific modeling and theory formation.
1.1.7 Expresses an awareness of the tentative nature of human knowledge.
1.1.8 Displays an interest in historical and/or contemporary scientific writings.

Subgoal 1.2 To recognize science as a human endeavor.

The learner:

1.2.1 States contributions to science and technology made by men and women of various ethnic groups and cultures.
1.2.2 Describes relationships between science and other areas of human endeavor.
1.2.3 Illustrates that scientific endeavor involves cooperation among individuals and groups.
1.2.4 Describes how human traits influence the strengths and limitations of scientific inquiry.
1.2.5 Lists examples of how scientists perceive the world in unique ways involving both direct and indirect observations.
1.2.6 Identifies factors such as funding, preparation, resources, time, and effort that influence scientific achievement.

Subgoal 1.3 To exhibit awareness of the orderliness and aesthetics in the environment.

The learner:

1.3.1 Identifies patterns in the environment.
1.3.2 Describes how humans have created schemes or patterns in their attempt to understand order in nature.
1.3.3 Describes how people interpret the aesthetics and orderliness of the natural and technological world in their creative work.
1.3.4 Describes feelings about aesthetic aspects of the natural and technological world.

Subgoal 1.4 To recognize interactions among science, technology, and society.

The learner:

1.4.1 Distinguishes science from technology.
1.4.2 Describes how the achievements of science and technology, when properly used, are basic to the advancement of human welfare.
1.4.3 Describes the consequences of past scientific and technological developments.
1.4.4 Considers the implications of new scientific and technological advancements.
1.4.5 Examines, in a critical way, print and non-print coverage of scientific issues.
1.4.6 Makes consumer decisions based on the findings of scientific research.
1.4.7 Formulates positions on environmental issues after consideration of available scientific information.
1.4.8 Demonstrates an appreciation and respect for living organisms.
1.4.9 Describes how science has enabled people to recognize their interrelationship with the environment.

Goal 2 To develop and apply, through science experiences, rational and creative thinking processes for problem solving.

Subgoal 2.1 To use observation to investigate the environment.

The learner:

2.1.1 Uses the senses to examine objects and events.
2.1.2 Identifies changes in objects and events.
2.1.3 Describes objects and events in comparative terms.
2.1.4 Discriminates observations from inferences.
2.1.5 Uses background knowledge to enhance the observation of objects and events.
2.1.6 Recognizes the need for appropriate instrument(s) to aid in observation.
2.1.7 Performs long-term observations.
2.1.8 Makes repeated observations to establish reliability.

Subgoal 2.2 To use questions for defining problems.

The learner:

2.2.1 Formulates questions from observations.
2.2.2 Identifies a question as testable or non-testable.
2.2.3 Defines a specific problem.

Subgoal 2.3 To use hypotheses as predictive tools.

The learner:

2.3.1 Predicts events or conditions based on observation and/or inference.
2.3.2 Identifies and applies appropriate information during hypothesis generation.
2.3.3 Generates testable hypotheses.

Subgoal 2.4 To conduct scientific investigations.

The learner:

2.4.1 Follows directions to complete a scientific procedure.
2.4.2 Identifies relevant variables in an investigation.
2.4.3 Distinguishes controlled variables from manipulated variables in an investigation.
2.4.4 Utilizes relevant information for establishing investigative procedures.
2.4.5 Identifies the importance of adequate sample size.
2.4.6 Identifies the importance of repeated trials.
2.4.7 Designs an investigation with one or more manipulated variables.

Subgoal 2.5 To organize data for the identification of trends and patterns.

The learner:

2.5.1 Identifies similarities and differences in a set of objects or events.
2.5.2 Groups objects and events according to similarities and differences.
2.5.3 Constructs a classification system to aid in grouping and identifying objects and events.
2.5.4 Employs accredited classification systems to aid in identifying objects and events.
2.5.5 Employs quantitative measurement as a criterion for analyzing data.
2.5.6 Arranges objects or events in sequence according to a particular criterion.
2.5.7 Determines appropriate procedures for analyzing data.
2.5.8 Employs graphs and figures to identify trends in experimental data.
2.5.9 Develops mathematical relationships from experimental data.

Subgoal 2.6 To use experimental evidence for evaluating hypotheses.

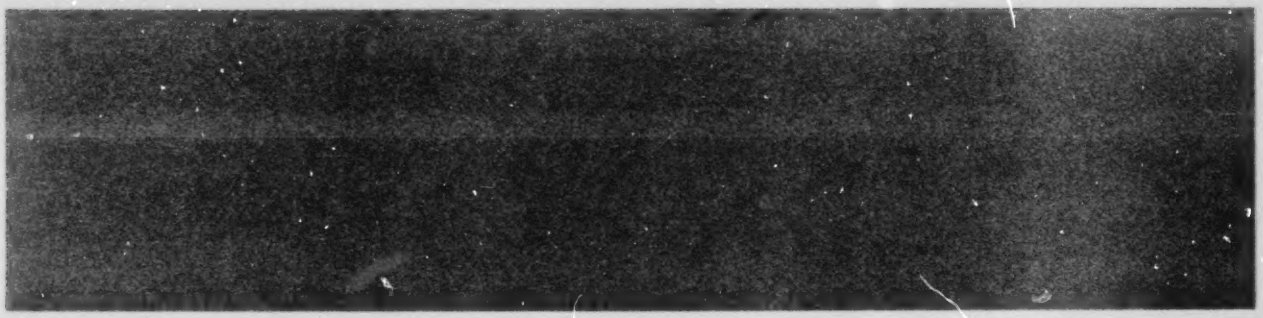
The learner:

2.6.1 Formulates conclusions from experimental data.
2.6.2 Compares results with predictions.
2.6.3 Discriminates significant from nonsignificant data.
2.6.4 Accepts or rejects hypotheses on the basis of experimental evidence.
2.6.5 Determines the validity of experimental procedures.

Subgoal 2.7 To apply the results of inquiry and critical thought.

The learner:

2.7.1 Uses patterns and trends derived from experimental data as a basis for examining related problems.
2.7.2 Reviews hypotheses after further observations.
2.7.3 Uses the results and conclusions of an experiment as a starting point for further investigation.



Goal 3 To employ the language, instruments, and materials of science for collecting, organizing, and communicating information.

Subgoal 3.1 To apply the appropriate skills and mathematical techniques necessary for collecting, organizing, and interpreting data.

The learner:

3.1.1 Observes characteristics of living and non-living things.
3.1.2 Classifies observational information into useful categories.
3.1.3 Quantifies information obtained from observations.
3.1.4 Obtains scientific information from a variety of sources.
3.1.5 Organizes information and data through the use of tables, charts, and graphs.
3.1.6 Interprets information from tables, charts, and graphs.
3.1.7 Uses appropriate mathematical manipulations to convert data into other useable forms.
3.1.8 Interpolates and extrapolates data.
3.1.9 Develops generalizations and predictions using the results of data analysis.
3.1.10 Assesses, within experimental error, the validity of conclusions established from an analysis of data.

Subgoal 3.2 To communicate in a manner that is consistent with scientific procedures.

The learner:

3.2.1 Utilizes listening skills for receiving information.
3.2.2 States questions, hypotheses, and working assumptions in a concise manner.
3.2.3 Employs scientific vocabulary when communicating ideas.
3.2.4 Explains methods and procedures used to conduct investigations.
3.2.5 Uses tables, charts, and graphs to communicate ideas.
3.2.6 Writes investigative reports which are supported by data and references.
3.2.7 Orally presents investigative reports which are supported by data and references.
3.2.8 Conveys accurately the findings and conclusions of laboratory investigations.

Subgoal 3.3 To use laboratory apparatus in a skillful manner.

The learner:

3.3.1 Manipulates tools of observation.
3.3.2 Selects appropriate tools for observation.
3.3.3 Manipulates tools of measurement.
3.3.4 Selects appropriate tools for measurement.
3.3.5 Manipulates tools used in material preparation and handling.
3.3.6 Selects appropriate tools for material preparation and handling.
3.3.7 Designs tools and apparatus as appropriate for science investigations.
3.3.8 Records data in a form which reflects the accuracy of tools and instruments.

Subgoal 3.4 To demonstrate proper techniques for handling, manipulating, and caring for science materials.

The learner:

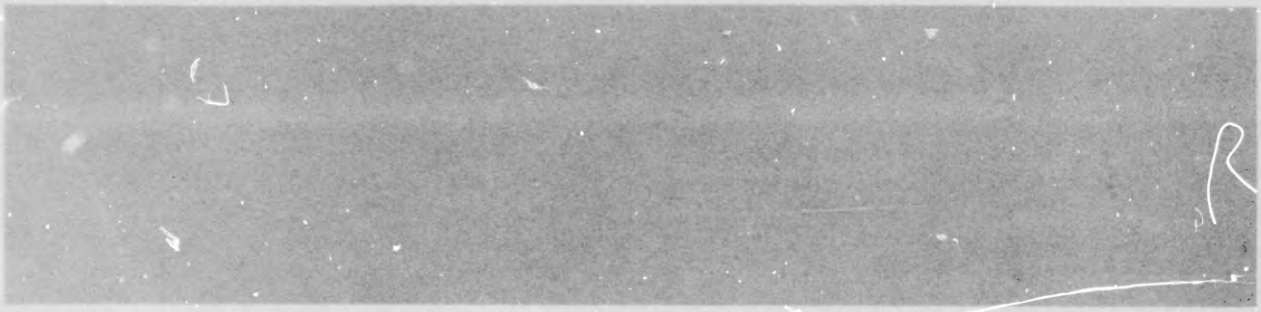
3.4.1 Practices established safety procedures in all scientific work.
3.4.2 Maintains appropriate life-supporting environments for plants and animals.
3.4.3 Cares for organisms in a responsible and legal manner.
3.4.4 Demonstrates proper techniques for cleaning, storage, and disposal of science materials.

Goal 4 To acquire and apply scientific knowledge—its concepts, theories, principles, and laws—to interpret the natural world.

Subgoal 4.1 To describe the nature of science.

The learner recognizes that:

4.1.1 Science is founded on the premise that all things, including "self-evident truths," are open to question.



4.1.2 Science searches for fundamental laws that apply throughout time and space.
4.1.3 Science is unique by virtue of its procedures for generating knowledge, and the nature of this knowledge.
4.1.4 Scientific progress depends upon experience and the accumulation of knowledge.
4.1.5 Scientific knowledge is tentative and is subject to continual review.
4.1.6 Scientific knowledge requires accurate measurements and observations, either direct or indirect.
4.1.7 Scientific endeavors require the honest and objective reporting and verifying of procedures, data, results, and conclusions of observation and experimentation.
4.1.8 Scientific inquiry is influenced by the beliefs, traditions, views, and actions of society.
4.1.9 Theories in science, whether logically derived or intuitively developed, are evaluated for their ability to explain past, present, and future phenomena.

Subgoal 4.2 To acquire and apply knowledge of the physical sciences—their concepts, theories, principles, and laws.

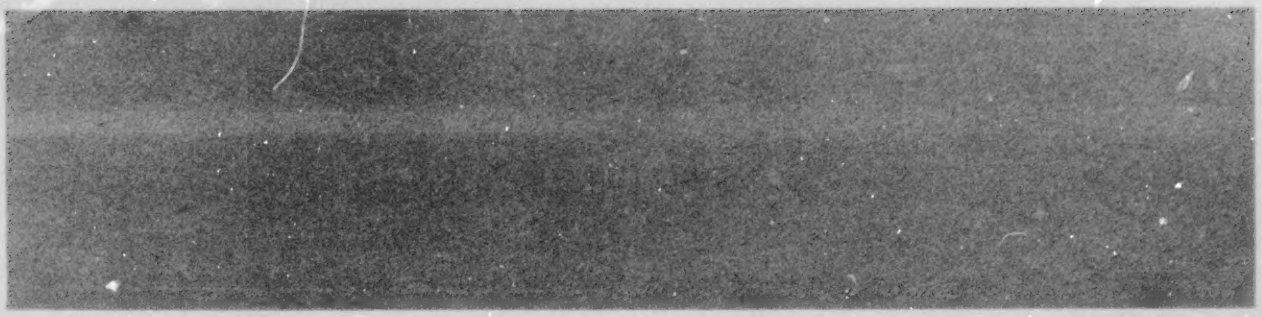
The learner:

4.2.1 Describes the properties of matter making use of length, mass, time, and frames of reference.
4.2.2 Distinguishes among the known fundamental forces in the universe.
4.2.3 Describes the motion of objects in terms of position, displacement, forces, velocity, acceleration, and time.
4.2.4 Discusses energy in its various forms and its interaction with matter.
4.2.5 States the properties of waves as they relate to transmission, interference, production, and absorption.
4.2.6 Describes electric, magnetic, and electromagnetic phenomena.
4.2.7 Identifies the atomic characteristics of matter.
4.2.8 Describes the concepts of astronomy from the viewpoint of physical science relationships.
4.2.9 Classifies samples of matter by their characteristic physical and chemical properties.
4.2.10 Interprets energy effects associated with physical and chemical changes.
4.2.11 Describes solutions qualitatively and quantitatively.
4.2.12 Interprets chemical information conveyed by chemical formulas and equations.
4.2.13 Performs calculations based on chemical equations including equilibrium systems.
4.2.14 Interprets behavior of matter in terms of the kinetic molecular theory.
4.2.15 Describes physical and chemical properties of elements from their placement on the periodic table.
4.2.16 Associates chemical behavior with electronic configurations of the atoms involved.
4.2.17 Explains the properties of substances in terms of the forces of attraction found within the materials.
4.2.18 Describes major categories of chemical reactions including: precipitation, acid-base, oxidation-reduction, complexation.
4.2.19 Accounts for the properties of characteristic organic compounds in terms of their structures and functional groups.

Subgoal 4.3 To acquire and apply knowledge of the life sciences—their concepts, theories, principles, and laws.

The learner:

4.3.1 Describes the characteristics of living things.
4.3.2 Describes structure and function in cells.
4.3.3 Describes processes by which matter enters and is transported throughout organisms.
4.3.4 Describes processes by which organisms capture, utilize, and release energy.
4.3.5 Describes processes by which internal balance of an organism is controlled.
4.3.6 Describes how an organism reproduces and transmits traits.
4.3.7 Describes the growth and development of organisms.



4.3.8 Describes how living things sense and respond to stimuli.
4.3.9 Describes biological aspects of the human species.
4.3.10 Describes species interaction and adaptation to an environment.
4.3.11 Describes the evolution of organisms.

Subgoal 4.4 To acquire and apply knowledge of the earth sciences—their concepts, theories, principles, and laws.

The learner:
4.4.1 Describes properties of minerals.
4.4.2 Describes characteristics of major rock types.
4.4.3 Relates crustal processes to landform developments.
4.4.4 Examines the determination and divisions of geologic time.
4.4.5 Examines the dynamics and effects of weather.
4.4.6 Explains how water affects various earth processes.
4.4.7 Examines the dynamics of the ocean system.
4.4.8 Describes the dependence of society on geologic resources.
4.4.9 Describes the earth's relationship to other astronomical bodies.

Goal 5 To utilize science experiences in the planning and fulfillment of personal aspirations and career decisions.

Subgoal 5.1 To relate science concepts and skills to vocations and avocations.

The learner:
5.1.1 Identifies science-related vocations and avocations.
5.1.2 Applies science skills and concepts to vocational situations and avocational pursuits.

Subgoal 5.2 To view persons in a variety of science-related vocations and avocations as role models.

The learner:
5.2.1 Gives examples of people of both sexes, in various age levels and ethnic groups who have made contributions to science and technology.
5.2.2 Demonstrates an awareness of work experiences of people in scientific vocations.
5.2.3 Identifies persons in the community who have science-related vocations and avocations.

Subgoal 5.3 To demonstrate vocational planning skills.

The learner:
5.3.1 Relates present science experiences to vocational requirements.
5.3.2 Uses resource information to examine potential vocations in science.
5.3.3 Identifies the various qualifications required for science vocations.
5.3.4 Examines vocations in science by considering personal interests, attitudes, and aptitudes.
5.3.5 Describes trends in the science and technology job markets.

Subgoal 5.4 To participate in creative science experiences that may enhance one's self-concept.

The learner:
5.4.1 Successfully completes a self-initiated classroom science investigation.
5.4.2 Successfully completes an independent science project.
5.4.3 Participates constructively in a group science activity.
5.4.4 Demonstrates divergent thinking during scientific inquiry.
5.4.5 Identifies with the creative human processes employed in the innovative use of resources and technology.

ILLUSTRATIVE OBJECTIVES

These sample objectives provide examples of ways to incorporate framework goals into local science instructional programs.* They are organized to give sample objectives for five different grade level groupings: K-2, 3-5, 6-8, 9-10, and 11-12. Grades 11 and 12 refer to advanced science courses.

Goal 4. To acquire and apply scientific knowledge—its concepts, theories, principles, and laws—to interpret the natural world.

Goal 4.3 To acquire and apply knowledge of the life sciences—their concepts, theories, principles, and laws.

Expectancy 4.3.1 The learner describes the characteristics of life.

During grades K-2 the learner:
Gives examples of life and distinguishes between living and non-living things.

During grades 3-5 the learner:
Identifies the basic necessities of living things.**

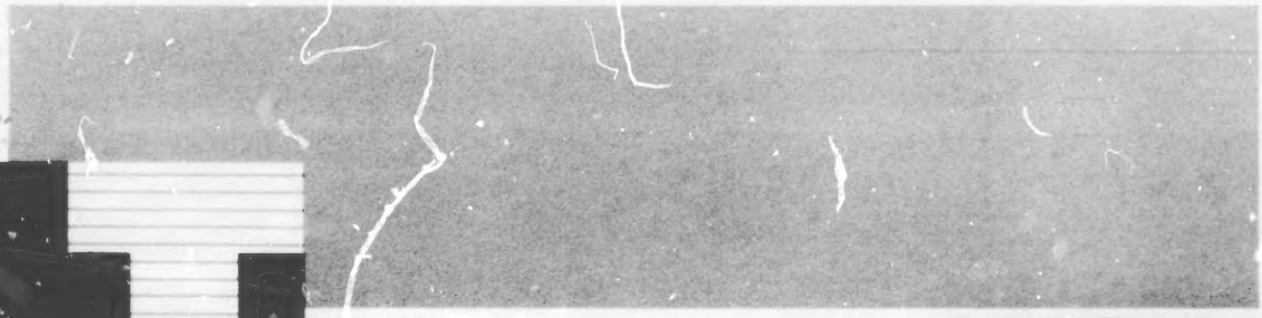
During grades 5-8 the learner:
Lists the similarities and differences between plants and animals.

During grades 9-10 the learner: (Biology)
Identifies the kinds of criteria used by taxonomists to classify organisms.

During grades 11-12 the learner: (Advanced Biology)
Outlines the role the DNA molecules play in determining the characteristics of organisms.

** These objectives are representative of a complete set of example objectives for each goal and subgoal which have been prepared under the direction of the Maryland Science Task Force. The complete set prepared by goal specific resource teams and consultants is available upon request from the Maryland State Department of Education.*

***This objective is an example of how a competency required for graduation in Maryland can be placed within the goals and subgoals of the Maryland science framework. A list of selected competencies required by the Maryland State Board of Education as graduation prerequisites with example placements within the science framework can be found in Appendix A.*



CURRICULUM ASSESSMENT AND DEVELOPMENT

This section is designed as a guide for curriculum specialists and teachers to assess existing curricula and develop new curricula. The material is organized around the four essential components of the written school curriculum: an underlying philosophy, the overall goals of the program, the scope and sequence, and the classroom instructional units. Each component is described in terms of its purpose, its specific elements, and assessment and development. In addition, an example from an existing Maryland curriculum guide is given for each component.

PHILOSOPHY

A philosophy is an explicit statement of the beliefs which should direct all aspects of a school system's curriculum. Developing a statement of philosophy allows educators in a system to reach consensus about the nature of the subject matter as it relates to the instructional program. A clear statement of philosophy, therefore, can aid the school system in developing goals, specifying instructional strategies, and assessing programs.

A comprehensive philosophy should begin by addressing the subject matter—its relationship to society and its relationship to learners. Based upon a synthesis of these elements, a clear position statement should be developed to direct the structuring of the curriculum.

The Subject Matter

This section should describe subject matter which is to be taught and the disciplines from which the curriculum should be drawn. It should address the underlying premises and values as well as the investigative strategies and processes inherent in these disciplines.

Society

Society's needs in relation to the subject matter should be of primary importance when planning a program. This section of the philosophy should describe these needs and how they can be met by a comprehensive curriculum.

The Learner

The system's set of beliefs about the needs of students is found here. These needs include those which are influenced by the external demands of society and those which, if met, would lead to personal fulfillment.

The Curricular Statement

The curricular statement is the culminating section of the philosophy. It synthesizes the needs of society and the learner with the subject matter content to produce a rationale for the curriculum.

Developing a Philosophy

To develop a program philosophy it may be useful to review the explicit philosophies in existence at the local, state, and national level. Implicit beliefs held by the local community should also be identified and considered. Finally, a system-wide consensus should be reached on the key beliefs outlined in the final product.

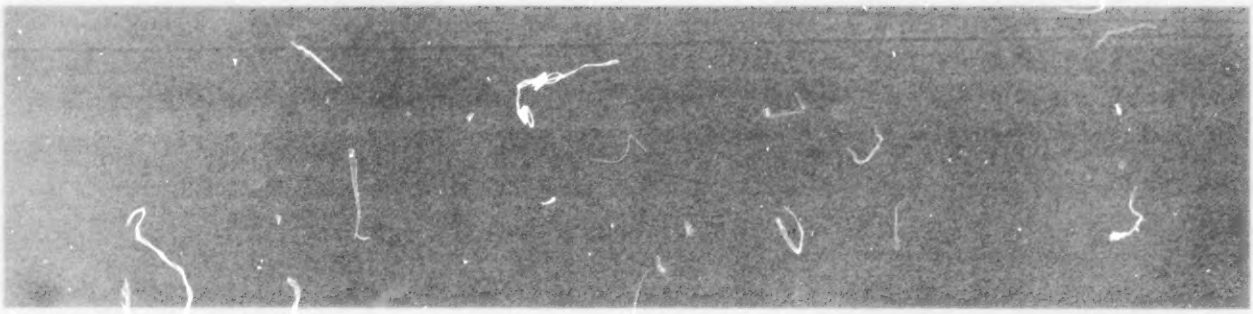
Example of a Local Science Education Philosophy

I hear and I forget
I see and I remember
I do and I understand

The essence of science is investigation of the material Universe. Its goals consist of a search for meaning; indeed Albert Einstein once defined it as experience in search of meaning; it seeks orderly explanations (conceptualizations) of phenomena, the objects and events about us. Nevertheless, there is stubborn insistence by scientists that an orderly explanation be testable. If a concept is not testable, it is usually not acceptable. Science is, in short, the "art of investigation" (Beveridge's term). But one cannot investigate an object or event if the object or event is not first perceived. Each concept attained is "synonymous with the operation" used to seek it.

Stated another way, if students are given the opportunity to become apprentices in investigation—to gain experience in search of meaning—they will come up to the present level of the culture of science. They will gain the legacy of science, its cumulative knowledge, as well as a way of gaining new knowledge. For the unknown is sought best by those who experience the known.

The curriculum used for teaching science is a blend of content and process. Students learn best when provided with content background as they participate in directed and active learning experiences. Teachers must teach science because society demands it. Helping students



undertake progressively more sophisticated intellectual activity is the central function of teaching. Creating productive situations (the learning environment) is the teacher's day-to-day responsibility.

GOALS

Goals are broad generalized statements which are derived from the philosophy and which determine the curriculum. They set the direction of the program by identifying those learner outcomes which are to be achieved through the program.

Since program goals are so broad, subgoals may be used to define the major areas covered by each goal. Additional levels of behavior statements may be written to further specify the expected behaviors within each subgoal.

Developing Goals

Goals should be developed from and thus reflect the system's philosophy. The chosen set of goals should at minimum incorporate all of the goals and subgoals from the state while addressing the specific needs of the community and special populations of children.

Example of a Local Set of Goals

The following comparison shows how a local set of goals have incorporated the required state science goals:

A LOCAL SET OF GOALS	STATE SCIENCE GOALS
1. To help the student know fundamental facts and principles of science.	Goal IV
2. To help the student possess the abilities and skills needed to engage in the processes of science.	Goals II, III
3. To help the student understand the investigative nature of science.	Goals II, IV
4. To help the student develop attitudes about and appreciations of scientists, science, and the consequences of science that stem from adequate understandings.	Goals I, V

SCOPE AND SEQUENCE

A scope and sequence is a picture of the entire curriculum from the school system level. It provides a broad overview of the content of the curriculum and illustrates the sequencing of the material from kindergarten through the twelfth grade.

In any scope and sequence it is important that certain key elements be presented for each unit or course: the title or topic, a narrative describing the content, the goals and subgoals to be taught, and the placement of the unit or course within the school program.

Developing and Assessing a Scope and Sequence

The first step for developing a new scope and sequence, or modifying an existing one, is to review the current curriculum. It may be helpful to answer the following series of questions about the current scope and sequence.

1. Are the topics covered adequate to meet the desired scope of the program?
2. Is the content, as well as its placement, appropriate for the developmental levels of the various types of learners?
3. Is each of the system's goals incorporated into the current scope?
4. Does the sequence follow a logical order and allow for recycling of material when appropriate?

The answers to these questions should be examined and recommendations made for needed changes in the scope and sequence. Once this needs assessment has been completed, the scope and sequence should be revised to reflect the newly developed philosophy and goals.

Examples from Local Sequences

There are a variety of ways a scope and sequence could be structured and still meet the recognized needs of a system. The following examples are comparisons of three different grade level *sequences* for K-12 science topics selected by different systems.

K-12 SCIENCE

MODELS

K

Colors
Exploring the Body
Likeness & Differences
Sounds
Weather & Seasons
Measuring
Plants and Pets

Observation
Describing
Comparing
Serial Ordering

Seasonal Changes
Seeds and Plants
Animals in the Classroom
Nutrition & Health

1

Using the Senses
Animals
Matter & its Properties
Plants
Mood & Mood Modifiers

Objects
Changes
Special Properties of Objects
Living Objects

Time
Growing Things
Changes in an Aquarium
The Senses
Moving Things

2

Water
Air
Weather
You & Plants & Animals
Magnetism & Electricity
Heat & Light

Properties & Matter
Interacting Objects
Spaces & Surfaces of Objects
Many Living Objects of a Kind

Weather
Investigating Matter
Insects
Classifying Animals
Thermometers Ice & Water

3

The Changing Earth
Plants
Health
Machines
Matter
Living Communities

Space & Motion
Interaction & Energy
Population Interactions
Variation in Objects & Systems

Looking into Space
Probing with a Microscope
Animal Needs & Care
Prehistoric Life
Drugs

4

Sound
Light
Air & Water
The Changing Earth
Environments
Animal Behavior

Exploring Matter
Exploring Energy
Patterns
Environments

Rocks & Minerals
Skin, Muscles & Bones
Exploring Outdoors
Sound

5

Man and Earth
Hidden Likenesses
Light and Color
Human Body
Adaptation to Changing Environment
Family Life

Forces
Motion
Matter & Energy
Adaptations

Atmosphere
Physical & Chemical Changes
Cells & Systems
Ecosystems
Drugs

6	Learning Natural Resources Harnessing Muscle Harnessing Electrons Probing the Stars Mood & Mood Modifiers	Models of Matter Models Energy & Ecosystems Population Needs	Exploring Space Oceans Nutrition Digestion Development of Self
7	*Life Science* The Living World Protists, Plants, Animals The Human Body Family Life & Human Development Ecology	*Life Science* Observing the World Systems of Life Life Activity The Environment Affects Living Things Living Things Affect the Environment	*General Science* Meteorology Models of Matter Characteristics of Living Things Diversity of Living Things Human Systems How Things Work
8	*Physical Science* Matter & Energy Atoms & Atomic Bombs Chemicals & Chemical Things Electricity & Magnetism Motion & Waves	*Physical Science* Force Motion Energy Matter	*General Science* Dynamic Earth Intro to Chemistry Changing Environment Changes in Living Things Energy
9	*Earth Science* Plate Tectonics Shaping the Land Minerals & Rocks People, Resources & Energy Air, Weather & Oceans Astronomy	*Earth Science* Earth History The Rock Cycle The Active Earth Meteorology/Oceanography	*General Science* Space Science Oceanography Human Behavior Genetics Wave Mechanics Electricity & Magnetism
10	Biology	Biology	Biology
11	Chemistry	Chemistry	Chemistry
12	Physics	Physics	Physics

Example from a Local Scope

The scope of each topic is described through a narrative and a listing of the goals and subgoals covered. Though two systems may teach the same sequence (that is, the same topic at the same grade level), the scope of that topic may be very different. The following are examples of scopes of science units taken from one life science course.

Seventh Grade: Life Science

UNIT I SCIENTIFIC THINKING

In this unit students will be introduced to science as a way of solving problems. Accurate observations are essential to this problem-solving process. Objective, measurable observations are a basic tool of all science and are necessary for formulating a reasonable and testable hypothesis. A hypothesis must be tested by a controlled experiment. An experiment designed to test this hypothesis must bring about results that can be accurately recorded and interpreted. Through hypothesizing and test designing students will develop skills that can be applied far beyond the science classroom. The content of this unit will include observations and inferences, developing hypotheses, experimenting and measurement and results.

Unit I addresses the following state subgoals:

1.1	2.1	3.1	4.1	5.4
1.2	2.2	3.2	4.2	
1.4	2.3	3.3		
	2.4	3.4		
	2.5			
	2.6			

[redacted]

UNIT II ECOLOGY OF THE BIOSPHERE

The student must understand the cyclic nature of matter and energy to appreciate the interrelationships existing within the natural world. The focus of the biome review is on the adapted forms of these relationships. While the conditions for life and the organisms involved may be different for various habitats, the types of interrelationships remain fundamental for the biosphere's dynamic existence. The content of the unit will include physical aspects and cycling of matter; relationships in nature (i.e., food chains and webs); populations, communities, aquatic biomes, sand biomes and mountains.

Unit II addresses the following state subgoals:

1.1	2.1	3.1	4.1	5.1
1.2	2.2	3.2	4.2	5.2
1.3	2.3	3.3	4.3	5.4
1.4	2.4	3.4	4.4	
	2.5		4.5	
	2.6			
	2.7			

[redacted]

UNIT III PROBLEMS OF THE BIOSPHERE

The biotic and abiotic interrelationships are applied for the student to understand the problems of pollution created by man's activities. An understanding of the problems of pollution and the types of conservation practices should aid the student in making decisions regarding their relationship within the biosphere. The content includes the pollution problem, conservation of soil, conservation of forests and wildlife, conservation of water, population growth.

Unit III addresses the following state subgoals:

1.1	2.1	3.1	4.1	5.5
1.2	2.2	3.2	4.2	
1.3	2.3	3.3	4.4	
1.4	2.4	3.4	4.5	
	2.5			
	2.6			
	2.7			

[redacted]

UNIT IV LIVING MATTER

This unit will show that to be considered alive, a living thing must carry on certain basic life functions. The students will be made aware that living things are composed of the same basic unit, the cell. Even though plant and animal cells differ, all cells share certain basic structures and functions. Finally, the student will see that cells are arranged into larger units of organs and systems. This content includes characteristics of living things, the cell and levels of organization.

Unit IV addresses the following state subgoals:

1.1	2.1	3.1	4.1	5.4
1.2	2.2	3.2	4.2	
1.3	2.3	3.3	4.3	
1.4	2.4	3.4	4.4	
	2.5			
	2.6			

[redacted]

UNIT V ORGAN SYSTEMS

As the student enters the adolescent years, knowledge of the body systems is necessary to understand the changes which will take place as the person matures. This unit will cover fundamental understandings of the various body systems and how they relate. The inclusion of the Al-Co-Hol material with this unit will aid students in making intelligent decisions about alcohol and drugs based on their knowledge of the body systems. The content includes the organ systems, circulatory system, respiratory system, excretory systems, nervous system, endocrine system, skeletal-muscular systems, and the effects of substance abuse on body systems.

Unit V addresses the following state subgoals:

1.1	2.1	3.1	4.1	5.1
1.2	2.2	3.2	4.3	5.2
1.3	2.3	3.3		5.4
1.4	2.4	3.4		
	2.5			
	2.6			
	2.7			

[redacted]

K-6

Example of a Local Match with a State Science Goal

To assess local programs, it is helpful to complete a match between goals established by the local system or the state and goals implicit in the current scope and sequence. The following is an example of such a match. It demonstrates that all of the subgoals for one state goal have been addressed at the elementary level and again at the secondary level.

CURRICULUM
ASSESSMENT
AND DEVELOPMENT

7-12

INSTRUCTIONAL UNITS

An instructional unit describes how a topic at a particular grade level is to be taught. It is a guide for teachers to use in working with their students.

An instructional unit consists of several important elements:

—the title or topic to be covered;

—a narrative or outline describing the content to be covered;

—a set of objectives derived from the goals and subgoals and defining the scope of the unit or course;

—the activities necessary to reach the objectives;

—a list of resources, equipment, and supplies;

—a description of the evaluation procedures needed to determine whether or not the objectives have been met.

How Are Instructional Units Developed?

The first step in the development process is to examine the existing instructional units. It may be helpful to ask a series of questions about the units:

1. Do the objectives build toward designated goals and subgoals and do they cover the scope of the topic?
2. Is the content, including skills, adequate enough to cover the topic and is it current?
3. Are the activities adequate for reaching the objectives and are they appropriate for the learner?
4. Is the sequence of learning activities within the unit logical?
5. Are the resources listed adequate for the activities?
6. Does the evaluation relate directly to the stated objectives?

After this needs assessment is completed, a series of decisions must be made. First, is it possible simply to revise the existing units? Second, if this is not possible, are there available units from an outside source that could be adapted to meet the identified needs? Third, if no such program is available, how can new units be developed locally to improve the curriculum?

Once these questions have been answered, it may be helpful to pilot any resulting curriculum changes. The evaluation of such a pilot can be useful in further refining the new curriculum.

Example of An Instructional Unit

GRADE: FIVE
UNIT: DRIPS, DROPS, AND BUBBLES

UNIT DESCRIPTION

During this unit students will explore the world of liquids. They will observe different kinds of liquids and discover their unique characteristics. Special emphasis will be placed on the cohesiveness of various liquids by studying individual drops. Surface tension will also be explored and compared for these various liquids.

Students will have direct hands-on experiences as they investigate these substances. The unit will stress the science skills of observing, inferring, predicting and controlling variables. There will be many opportunities for students to conduct their own investigations, draw their own conclusions and communicate their findings to others.

UNIT GOALS:

The following state science subgoals are addressed in this unit:

1.1 To recognize science as a worthy endeavor
2.1 To use observation to investigate the environment
2.3 To use hypotheses as predictive tools
3.4 To conduct scientific investigations
3.5 To organize data for the identification of trends and patterns
3.6 To use experimental evidence for evaluating hypotheses
3.7 To apply the results of inquiry and critical thought
4.1 To apply the appropriate skills and mathematical techniques necessary for collecting, organizing and interpreting data
4.2 To communicate in a manner that is consistent with scientific procedures
4.4 To demonstrate proper techniques for handling, manipulating, and caring for science materials
5.2 To acquire and apply knowledge of the physical sciences—their concepts, theories, principles and laws
5.4 To participate in creative science experiences that may enhance one's self-concept

UNIT OBJECTIVES:

By the end of this unit the student should be able to:
Observe, describe, record, and discuss behaviors of liquids on various surfaces
Predict the heaping behavior of a liquid based on observations of its drops
Predict the behavior of a liquid based on its surface tension
Compare the splash marks made by various liquids
Create an effective bubble blowing chemical through the manipulation of several variables
Construct devices for creating different types of bubbles
Construct devices to produce a variety of soap films

VOCABULARY

Liquid
Surface Tension
Detergent

SUGGESTED ACTIVITIES:

1. ***Water Drops:*** Have students observe and record their observations of drops of water on a piece of wax paper. They should be answering some of the following questions:
   What shape does a drop have (top new, side new, etc.)?
   How does it behave?
   Can a drop be separated into smaller drops?
   What happens when you trail your findings through a drop?
   Can a drop be made higher?

2. ***Comparing Drops:*** Have students compare the characteristics of the drops of several liquids on wax paper (plain water, soapy water, cooking oil, salt water, alcohol, milk, etc.). They should first label the wax paper with masking tape and then put on a drop of each liquid by its name. They should be answering some of the following questions:
   How are these liquids different from water?
   Which liquids produce the highest drop? the lowest?
   Which liquids stay together best as their drops are moved?
   What happens to the drops when two liquids are mixed?

The students' results should be recorded and saved.

3. ***Heaping:*** With a partner have students fill a small plastic container with water. Each should then predict how many additional drops of water the container can hold before overflowing. Students can then investigate the actual amount by using more water and eyedroppers. They should be observing the container from the side as well as the top. The phenomena they will be observing as they see the water rise above the level of the container is called heaping.

For fun, have students fill a plastic glass with wa... then predict the numbers of paper clips that can be added before it overflows. Then have them see how close they came.

Finally, have students review the results of the comparison of the drops made by various liquids and predict how those liquids behave when you attempt to heap them. Then have them test their predictions.

4. ***Spatter Prints:*** Have students investigate the prints made by dropping plain water, soapy water, and diluted tempura paints through eye droppers or straws onto construction paper. They should record their procedures and results. Some questions they could be answering:
   How does height affect the drop?
   How does type of liquid affect the drop?
   How does angle of the paper affect the drop?
   How many lines radiate from a splash and does this number vary from splash to splash?

Have students design an art paper using their knowledge of spatter prints.

Working in pairs, have students try to duplicate a mystery spatter print made by their partners.

Have students investigate the effects that different surfaces (blotters, foil, cloth, etc.) have on spatter prints. They should record and report their results.

5. ***Comparing How Different Surfaces Affect Different Drops:*** Have students work in teams of two, three, or four. Provide each team with a different liquid, eye droppers and different surfaces, (e.g., waxed paper, aluminum foil, plastic wrap, glass, newspaper, cloth). Have each team investigate how a drop of its designated liquid behaves on each of the different surfaces. Then have the group report its findings to the class so that the liquid can be compared to others. Students should be answering some of the following:
   Do different surfaces affect drop size or shape?
   Which surface allows the drop to spread out the most?
   Which surface causes the highest bead? the lowest?
   On which surface can the drop move best?
   What happens when the drops are pushed together?

6. ***Surface Tension:*** Have students "float" a paper clip on water using another paper clip as a cradle.

Then have them observe the surface of the water. Next have students investigate what happens when a drop of soap is added to the water. Discuss this reaction.
Other illustrations: ***Chase the Pepper***—Wash a saucer with clean water and fill it with cold water. When the water is still, have students sprinkle pepper on it. Now drop some detergent on the edge of the dish and watch! Why might this have happened?

Floating Screens: Have students float a piece of wire screen. Then have them gently place some small washers on it. They can then predict how many washers it will hold before it breaks the surface tension. Some could go farther and try to modify and test this prediction after doubling the size of the screen.

7. ***Making the best "Bubble Stuff":*** Given the three ingredients of water, liquid detergent, and glycerin have students manipulate the variables until they have the best formula for "bubble stuff." They may need to start with just detergent and water and then progress to the effects that adding glycerin will have. Be sure that students record all their trials so when they arrive at the best they will know how to duplicate it. A contest can even be held to discover the "winning bubble stuff" if the other variables for blowing bubbles can be kept constant.

A simple bubble blower can be made from a straw by making four cuts about 1 cm long at the end and curling the strips back.

After creating their own bubble solutions, children can develop advertisements for their product.

8. ***Bubble Blowers:*** Arrange an assortment of materials on a table in the classroom. List these materials on the board. Explain to students that they will be devising their own bubble blowers for their own purposes, big bubbles, tiny bubbles, longer lasting or stronger bubbles, bubbles with smaller bubbles inside, etc. First they must design on paper their device and explain its purpose and the materials needed to construct it. Then, they can get what they need and test their device.

For fun, have them try to blow square bubbles, make three dimensional blowers, or use bubble solutions with food coloring added.

SUGGESTED ASSESSMENT ACTIVITIES:

1. Devise a checklist of desirable laboratory behaviors and evaluate laboratory skills during class.
2. Give students an unknown liquid and ask them to record their observations of its behavior as a drop on three specific surfaces.
3. Have students save their reports of their investigations and establish criteria on which to evaluate them.

RESOURCES FOR TEACHERS

Boys, Charles Vernon. *Soap Bubbles.* New York: Dover, 1959

Devito, Alfred and Gerald H. Krondonu. *Creative Sciencing: Ideas and Activities for Teachers and Children, Sec. Ed.* Boston: Little Brown & Company, 1980

Kitchen Physics, McGraw Hill

Abruscato, Joe and Jack Hassard. *Whole Cosmos Catalogue of Science Activities.* Glenview, Illinois: Scott Foresman, 1976

BOOKS FOR STUDENTS:

Zubrowski, Bernice. *Bubbles.* Boston: Little Brown and Co., 1979

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APPENDIX C

Required Maryland Graduation Competency Objectives and Examples of Placement Within Framework Goals and Subgoals

The following are examples of how required Maryland graduation competency objectives can be placed within the science framework by local school systems. These examples from the *Declared Competency Index* of the Maryland State Department of Education are listed by framework goal and subgoal.

GOAL I. To develop positive attitudes toward science and its relevance to the individual, society and the enviroment.

Subgoal 1.4 To recognize interactions among science, technology and society.

Example minimum competency objectives:

2.2.1.1 Describe how humans are part of an environmental system
2.2.1.2 Describe ways to conserve natural resources
2.2.1.6 Explain the major types of pollution in the environment.

GOAL III. To employ the language, instruments, and materials of science for collecting, organizing and communicating information.

Subgoal 3.1 To apply the appropriate skills and mathematical techniques necessary for collecting, organizing and interpreting data.

Example minimum competency objectives:

2.3.1 Use information from tables
2.3.2 Use information from graphs

Subgoal 3.3 Use laboratory apparatus in a skillful manner.

Example minimum competency objectives:

2.2.1 Read scales on measuring instruments.

GOAL IV. To acquire and apply scientific knowledge—its concepts, theories, principles, and laws—to interpret the natural world.

Subgoal 4.3 To acquire and apply the knowledge of the life sciences-their concepts, theories, principles, and laws.

Example minimum competency objectives:

2.1.1.1 Describe the positive and negative effects of drugs on the human body.
2.1.1.2 Describe the positive and negative effects of food on the human body.
2.1.1.3 Identify personal health practices.
2.1.1.8 Describe functions of the systems of the human body.
2.1.1.9 Identify the symptoms of common illnesses.
2.1.1.14 Identify the basic components of a well-balanced and nutritious diet.
2.1.1.15 Identify methods for the prevention and control of communicable diseases.
2.2.1.4 Identify the basic necessities of living things.

GOAL V. To utilize science experience in the planning and fulfillment of personal aspirations and career decisions.

Subgoal 5.1 To relate science concepts and skills to vocations and avocations.

Example minimum competency objectives:

4.2.1.2 Identify occupations which relate to personal interests, aptitudes and values.

Subgoal 5.3 To demonstrate vocational planning skills.

Example minimum competency objectives:

4.1.1.19 Identify basic requirements for employment in specific jobs.
4.4.1.3 Identify alternative personal career goals.
4.4.1.6 Identify educational opportunities available in selected careers.
4.4.1.7 Identify criteria for selecting programs, schools and courses designed to prepare an individual for a job.
4.4.1.20 Use school and community resources to obtain career information.

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